A STUDY OF THE INFLUENCE OF SURROUNDING MEDIA AND SURFACE TREATMENTS ON THE STRENGTH OF GLASS

BY

VARTHAKAVI KRISHNA MOORTHY

M.Sc., Andhra University, 1946
M.S. University of Illinois, 1950

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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ACKNOWLEDGEMENT

The author wishes to express his sincere gratitude to Professor F. V. Tooley, for his valuable guidance, kind advice and constant encouragement throughout the work and to Professor A. I. Andrews, Head of the Department of Ceramic Engineering for his encouragement and keen interest in the progress of the work.

Grateful acknowledgement is made to Professor G. F. Stockdale for his help and cooperation throughout the investigation.

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A STUDY OF THE INFLUENCE OF SURROUNDING MEDIA AND SURFACE TREATMENTS ON THE STRENGTH OF GLASS

Introduction:

The effects of surface treatments and the influence of the surrounding media on the strength of glass has not been studied in detail. Stockdale, Tooley and Ying[1] studied the effects of water soaking treatments (at 90°C) on three types of glasses and reported increases in strength in all the cases. They also noticed a decrease in strength when freshly prepared specimens were broken under water. It was not possible to give a unique explanation of the lowering in strength of the glasses in water and increases in strength after soaking treatments.

The purpose of this investigation was to study the strength of glass in liquid media other than water in an attempt to determine the factors responsible for the changes in strength. Relatively simple liquids were chosen for the study.

Experimental Procedure:

The constricted fiber technique was used in this study. A glass of the composition SiO_2 73%, Na_2O 17%, CaO 5%, MgO 4%, and Al_2O_3 1% was used.

The preparation of the specimens involved the following steps. First a rod 0.035 - 0.050 inches diameter was drawn from a glass rod 0.4 inches diameter using an electrically heated furnace, held at a temperature of 790 ± 5°C in the center zone. A 2 kg load was used for the draw. This rod was cut to pieces about five inches in length. Balls for suspending the specimens in the breaking apparatus were formed on both ends of these pieces, using a platinum wound furnace operating at 1000 - 1200°C. For forming constrictions in the fiber, a small tube furnace held at 760 ± 5°C was used,

and the specimens were drawn using a load of 500 grams. Two constrictions were made in each rod — one in each half of it. The rod was cut in the middle and balls formed at the ends, thus resulting in a pair of specimens from each original five inch rod. The specimens were annealed at 490°C and cooled gradually to room temperature. One specimen from each pair was used for controls and the other for the test. 72 specimens were used for controls and 72 for the test in each of these experiments.

The strength of the specmens was determined by breaking under tensile loading. The specimen was held between two socket chucks; the bottom chuck supported an enamel bucket. Mercury was loaded into the bucket at a constant rate. When the specimen broke the bucket was arrested by two supporting metal hooks, thereby closing the circuit of the relay which shut off the mercury flow automatically. The mercury bucket was then weighed and the diameter of the fiber at the break was measured with a vernier micrometer reading to 0.0001 inches. Data on specimens which did not break at the thinnest section was discarded.

The control specimens were broken under water and the changes in strength are referred to this standard.

Data and Discussion of Results:

The data is presented in table 1.

Influence of surrounding media:

Breaking under monohydric alcohols, glycerol, phenol, anisole and acetone resulted in significant increases in strength. Breaking under benzene, heptane and mercury resulted in increases comparable to breaking in air. The strength in nitro-benzene was significantly lower than in nitro-propane.

When specimens were broken under straight chain alcohols increases in strength resulted. Increases were less as the length of the chain increased.

The above results cannot be readily explained on the capillary flaw concept suggested by Stockdale, Tooley and Ying[1] to explain the strength changes in water soaking treatments. An explanation is suggested on the basis of interfacial reactions between the glass surface and the surrounding liquid molecules. According to the present concepts of the structure of glass, the glass surface would consist mainly of oxygen atoms with a little contribution by the silicon and modifier atoms i.e. consists of large negatively charged zones with a few positively charged zones here and there. The modifier ions on the surface are relatively mobile compared to the silicons and oxygens which are tied up in the network. Strength increases would be observed when the surrounding molecules can satisfy the negative charges of the oxygens more evenly. The shape and size of the alcohol molecule determines the resultant positive charge on the hydrogen and the ease with which the molecules can be attached to the glass surface; hence the resultant change in strength. The homologous series of normal alcohols where the increases in strength were progressively smaller with increasing size of the molecule, and the different effects in normal and tertiary butyl alcohols illustrate this point. The increases in strength in glycerol, phenol, anisole and acetone can be partially explained on the basis of the same concepts. Nonpolar liquids would not be expected to have any effect. This is well illustrated by the results obtained with benzene, heptane and mercury. A possible explanation of the differences in the changes in nitro-benzene and nitro-propane is suggested on structural considerations.

Soaking treatments:

The strength changes due to soaking treatments are brought about by the change in surface condition of the specimens. Such changes are possible only when the liquid can react with the glass. Thus polar liquids i.e. water and methyl alcohol caused strength changes on soaking, while soaking in benzene (nonpolar liquid) had no significant effect on the strength.

The two effects - change due to soaking in a liquid medium and change due to breaking under another liquid - seem to be independent and approximately additive. This is illustrated by experiment 15.

BIBLIOGRAPHY

(1) "Increase in tensile strength of glass caused by water immersion treatment"
Stockdale, Tooley and Ying, J. Am. Cer. Soc.; 34, 116, 1951.

TABLE I

Serial number	Details of experiment	*Percent change in strength.
1	Broken in air	+ 9.12 ± 5.97
2	Broken in methyl alcohol	+ 35.92 ± 8.67
3	Broken in glycerol	+ 19.50 ± 4.76
4	Broken in n-heptane	+ 10.01 ± 6.02
5	Broken in benzene	+ 9.99 ± 5.12
6	Broken in acetone	+ 17.6 ± 4.40
7	Broken in mercury	+ 10.1 ± 6.58
8	Dipped in methyl alcohol, dried in air broken in air	+ 12.2 ± 5.01
9	Broken in sodium chloride solution (1%)	− 2.43 ± 5.28
10	Broken in toluene	+ 10.6 ± 5.40
11	Broken in nitro-benzene	− 1.45 ± 5.22
12	Broken in anisole	+ 16.3 ± 6.81
13	Broken in n-octyl alcohol	+ 19.6 ± 6.80
14	Broken in phenol	+ 17.8 ± 5.92
15	Soaked in water for 48 hrs at 60°C; broken under methyl alcohol	+ 70.1 ± 7.34

* Referred to strength of specimens broken under water.

Serial number	Details of experiment	*Percent change in strength.
16	Soaked in methyl alcohol at 40°C for 24 hrs; broken under water	+ 3.67 ± 6.37
17	Soaked in methyl alcohol for 24 hrs at 40°C, broken under water	+ 22.4 ± 5.44
18	Soaked in methyl alcohol at 40° C for 24 hrs, broken under alcohol	+ 41.2 ± 5.49
19	Soaked in benzene for 24 hrs at 40°C, broken under water	— 2.5 ± 5.49
20	Broken in methyl alcohol - water mixture (Molar ratio 1:1)	+ 8.95 ± 5.60
21	Broken in n-butyl alcohol	+ 21.7 ± 5.35
22	Soaked in methyl alcohol at 40°C for 12 days, broken in air	+ 19.0 ± 8.09
23	Broken in t-butyl alcohol	+ 33.3 ± 6.13
24	Broken in isopropyl alcohol	+ 21.8 ± 5.28
25	Broken in ethyl alcohol	+ 27.9 ± 6.92
26	Broken in nitropropane	+ 14.0 ± 6.01

* Referred to strength of specimens broken under water.

VITA

Varthakavi Krishna Moorthy was born in Madras Province, India on March 10, 1925. He received his high school and part of his college education at the P.R. College, Cocanada. In June 1941, he joined the Chemistry department of the Andhra University and received the B. Sc (Hons) degree in 1944, and the M.Sc degree in 1946. During the period 1944 - 48, he was a research assistant (to the Council of Scientific and Industrial Research) at the Andhra University. He entered the University of Illinois in the fall semester of 1948, and obtained the M.S, degree in Ceramics in 1950.

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